DOCUMENT RESUME

ED 362 206 IR 016 362

AUTHOR Strommen, Erik
TITLE Preschool Children at the Interface: A Cognitive Model of Device Difficulty.
PUB DATE Jan 93
NOTE 10p.; In: Proceedings of Selected Research and Development Presentations at the Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (15th, New Orleans, Louisiana, January 13-17, 1993); see IR 016 300.
PUB TYPE Reports - Evaluative/Feasibility (142) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; Data Analysis; *Difficulty Level; *Man Machine Systems; Memory; *Microcomputers; Models; Performance; *Preschool Children; Preschool Education
IDENTIFIERS Childrens Television Workshop NY; *Cognitive Modeling; Computer Interfacing; *Computer Users

ABSTRACT

Because of the lack of error-free, on-task performance by young children, cognitive modeling has not generally been considered an appropriate technique for characterizing computer use by young children. It is argued that cognitive modeling can be a useful strategy for organizing data on children's performance when the domain being studied is appropriately defined. The domain of interface devices for computer control and their demands on young children as computer users is used in this example, which reviews the results of several studies of children's use of a variety of different input devices conducted at the Children's Television Workshop. The cognitive modeling hypothesis suggests that for young children the degree to which cursor movement devices resemble natural motions (such as pointing) makes use easier. The more rules of use a device requires, the more difficult it will be for the child to use because working memory will be consumed in a manner similar to the use of the device itself. The model assumes that the demands of cursor control and device rules are additive. The model is applied to children's task performance in several studies. The current model shows promise as a framework for analyzing children's performance with different input devices and explaining and predicting differences in competence across devices and across children. Two tables illustrate the discussion. (Contains 12 references.) (SLD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED 362 206

Title:

Preschool Children at the Interface: A Cognitive Model of Device Difficulty

Author:

Erik Strommen

IR016362

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Michael Simonson

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Cognitive modeling is a method by which data on human performance is quantified and interpreted. In the field of human-computer interaction, cognitive models provide theoretical constructs that attempt to identify the mental processing required to perform a given class of computer tasks, and which try to provide explanations for variations in performance across users and across tasks. Many different types of models exist in the current human-computer literature (c.f. Booth, 1989; Olson and Olson, 1990), and have been successfully applied to a range of computer-based tasks, such as word-processing or automatic-teller usage. It is often argued that this type of modeling provides the most profitable way to assess and predict human performance with the computer, and allows the most penetrating insight into the factors that govern effective human-computer interaction.

While cognitive modeling has been a useful technique for characterizing adult computer use, the suitability of this method for understanding the performance of young children is limited. The basic problem is that for such models to have any predictive value, they must assume generally error-free, on-task performance by the computer user, and that the user's performance is always directed toward solving a clearly defined goal (Booth, 1989; Olson and Olson, 1990). Casual use, where there is no clear goal, or use behavior that is filled with errors or digressions, is not well-captured by cognitive models. Unfortunately, such behavior is typical of preschool children, and thus would appear to make cognitive modeling unsuitable for understanding the performance of such children when using a computer.

The present paper takes the position that cognitive modeling can still be a useful strategy for organizing data on children's performance with computers if the domain being studied is appropriately defined. The current model is concerned with the narrow domain of interface devices for cursor control, and their demands on young children as computer users. The purpose of the model is to provide an initial explanation for the results of several studies of children's use of a variety of different input devices, conducted in the past five years at Children's Television Workshop. **This explanation should be regarded as provisional; future studies will attempt to refine the hypotheses presented here.**

The model

The model begins with the view that cognitive development is accomplished by (1) the acquisition of new concepts, and action schemata, in long term memory; and (2) general increases in cognitive processing power, or short-term working memory, that allow these rules to be efficiently recalled and used dynamically in actual situations (c.f. Case, 1985; Pascual-Leone and Ijaz, 1989). This conception of cognitive growth suggests that young children "fail" tasks that older children and adults can solve because (a) they do not know all the concepts required to perform a given task; and/or (b) they may know all the necessary concepts but lack the mental storage space to activate them all together when needed. Under this theory, young children (the focus of the present model) lack both elements of successful performance. They not only may lack the knowledge required to use a given input device - and need to learn it, a task requiring cognitive effort - but they may also lack the working memory to actively utilize all the knowledge they do have.

The domain of behavior being described is children's competence of use, both initially and after practice, of different "pointing" devices, all of which have the common functions of (1) directing a cursor to select icons on a screen; and (2) activating those icons via a confirmatory keystroke or button press. This behavior is considered to have two additive psychological components: The cognitive demands of cursor control as a behavior, and the pragmatic demands, or "rules," of the hardware device itself that must be followed during use. Both of these components require the activation and use of information that must be either learned or drawn from long-term memory, and both components require working memory during their activation and use.

Cognitive demands of cursor control

This model begins from the assumption that the most natural way for a young child to make choices via a graphic interface is through physical actions that are already natural and familiar to the child, in this case: pointing. Pointing to pictures in books, or to desired objects in the store, school, or home, is a behavior established in infancy. It is assumed here that pointing requires no cognitive effort on the child's part: It is an automatic motor behavior whose execution is completely routinized, with no conscious effort required for its performance. In other words, no working memory is required when the child only needs to point to a choice.

Most computer input devices take advantage of pointing as an easy, swift method for making choices. Evaluations of the design and properties of computer pointing devices recognize that these cursor control devices usually conserve various combinations of the three fundamental properties of human movement that play a role in pointing: direction, distance, and speed (Buxton, 1986; Mackinlay, Card, and Robertson, 1990). The mouse, for example,

conserves all three properties of the user's physical movement in the cursor. The mouse's motion on the tabletop is precisely mimicked on the screen by that of the cursor, and positioning the mouse is equivalent to pointing a finger at a choice. The joystick, in contrast, only utilizes the direction of the user's movement. Speed is fixed by the machine, and distance is determined by how long the shaft is pressed - not by any actual distance of the user's movement.

For the present paper, it is argued that the less a pointing device conserves the three properties of movement, the more demanding it will be for young children to use. This increase in difficulty as devices become less like pointing is hypothesized to be due to the fact that children must exert more mental processing effort to anticipate, and evaluate, the movement of the cursor when their own movements are not conserved by it, and that this effort increases with each property of their own movement that is not conserved by the input device. In a sense, the less the cursor responds directly to their own actions, the more it moves "independently" of them, and they therefore must allocate more mental resources to monitoring its movement than they would if it were completely mapped onto their own movements. The model assumes that the mental resources (attention to cursor position and motion, planning of cursor movement, etc.) required when an input device does not conserve the child's own movement are significant, and relatively stable - they do not diminish significantly with experience.

Rules of device use

While the cursor's movement on the screen must be attended to, there is another demand the child must attend to: The rules of device use. Every input device must be used in a specific manner if it is to be used successfully. The particular actions that must be performed with the device to move the cursor (sliding a mouse, rolling a trackball, etc.), other specific actions (keeping a device in the correct orientation, pressing a button to confirm a choice), and other cognitive elements (such as translating the directions of movement of the device to the cursor on the screen) vary with the device used.

This model presents the hypothesis that the more such rules a device requires for use, the more difficult it will be for children to use easily and efficiently, because they consume the child's limited working memory capacity in a manner similar to the demands of cursor control itself. However, unlike the cognitive demands of cursor control described above, this model proposes that device rules differ from cursor control in two ways. First, it is hypothesized that these rules require less resources than cursor control. Second, unlike cursor control, device rules are easily assimilated with experience, and they quickly become "chunked," or automated (Case, 1985), ceasing to require active cognitive processing when they are being invoked. In other words, repeated practice with the rules of device use quickly causes them to become habitual and unconscious, so that

the same set of rules comes to require less cognitive effort over time than they required initially.

Relation between demands of cursor control and device rules

The model is based on the hypothesis that the demands on working memory by both cursor control and device rules are additive. That is, the combination of the mental effort required for cursor control and that required for remembering all devices rules sums to the total demand that a particular device makes of the child user. It is hypothesized that children's competence with a given input device is impaired when the combined load on working memory of cursor control and device rules exceeds the child's current working memory capacity.

An additional hypothesis is that when the extra demands of the actual software task itself (solving math problems, finding correct letters, etc.), combined with the demands of the device, exceed the capacity of the child's working memory, the child's ability to control the cursor will be impaired before the child's ability to solve the problems presented by the software. That is, the child will still be able to solve the problem presented by the computer, but will be unable to respond effectively using the input device.

Performance explained by the model

In a series of studies comparing children's use of various input devices (Revelle and Strommen, 1990; Revelle, Strommen, and Offerman, 1990; Strommen, 1993), and in research on specific devices as well (Strommen, 1992; Strommen, Razavi, and Medoff, 1992; Strommen and Revelle, 1990), the results indicated a consistent ranking of devices in terms of the ease of with which children can use the devices to place a cursor on an icon on the television screen (ease is defined both in terms of length of time required to place the cursor, and in terms of total accurate cursor placements). This rank ordering is shown in both Tables 1 and 2, along with an initial analysis of the cognitive demands of both cursor control and use rules for each input device. This ordering is consistent with the hypothesis that the more removed a device gets from the actual physical act of pointing by the child, the more cognitive resources are required by the child to use it effectively.

In addition, the inclusion of device rules explains a unique finding in the three major studies: children's performance with the trackball is consistently superior to that the mouse in the first few days of use. Note that the trackball and the mouse both conserve all three of the dimensions of the child's own actions, suggesting that they make the same demands of the child in terms of cursor control. However, the mouse has many more pragmatic rules associated with its use. These rules hinder children initially, but after several days of practice their competence with the mouse quickly rises to the high level of performance seen right from the start with the trackball.

Current issues confronting the model

Level of detail of the analysis

The current model rests on an assessment of the cognitive demands of cursor control and device use rules. A persistent problem with cognitive modeling techniques is determining the appropriate level of detail that the model needs to specify in order to be accurate: "...the most common predictor of cognitive complexity is the number of rules that are required to describe a task. Unfortunately, the number of rules that are generated by any modelling technique may be dependent not only upon the true complexity of the task, but also upon the grain of the analysis employed (Booth, 1989, p.92)." It is not clear that the analysis of the device rules, or the analysis of cursor control in terms of the three dimensions of pointing behavior, is sufficiently detailed or is too detailed. The validity of the pragmatic device rules, in particular, needs to be more carefully investigated.

A second issue is determining the true cognitive load that the various forms of cursor control actually impose, and the true cognitive load of the device rules, as well. The model current assumes that the cognitive demands of cursor control increase in direct ratio to the loss of movement dimensions conserved. For example, if device rules were all equal, it is assumed that the mouse and trackball would make equal memory demands, and that both would make equally less demands than the joystick, which conserves only one aspect of movement instead of all three. Similarly, the model currently assumes not only that the device rules are all equal in their memory demands, but that they require less cognitive resources than cursor control as a mental act. How much less demand they make is not known. All these assumptions need to be experimentally verified.

Finally, research that links working memory capacity to children's competence when using different input devices needs to be conducted. The current model relies on a specific theory of cognitive development that quantifies working memory in measurable ways. If the present model is correct, it should be possible to associate children's measured working memory with their performance using different input devices.

In conclusion the current model shows theoretical promise as a framework for analyzing children's performances with different input devices, and explaining and predicting differences in competence not only across devices but across children (with differing working memory capacities) as well. It has the potential to provide the first specific conceptual link between developmental psychological theories and children's ability to use interactive technologies, by incorporating competence with input devices into an existing theoretical framework. The model is inadequately specified at present, and specific empirical tests of its constituent features is needed.

Table 1. Cursor control demands of standard input devices, listed by overall ease of use by preschoolers.

Device	Cursor control demands
Touchscreen	None: identical to physical act of pointing
Light pen	None: same as pointing, but with an object as the pointer
Trackball	Minimal: Speed, duration, and direction of ball rotation (child's movement) translate directly into cursor movement.
Mouse	Minimal: Speed, duration, and direction of mouse movement on surface (child's movement) translate directly into cursor movement
Joystick	Moderate/Heavy: Direction is only aspect of physical movement conserved by device
Arrow keys	Heavy: No aspect of movement is conserved by device(s). Directions are separated into unique keys requiring extra step of planning of movement by user.

Table 2. Rules of use of standard input devices, listed by overall ease of use by preschoolers.

Device	Device-specific use rules
Touchscreen	1. Touch desired icon with finger 2. Press button or key to confirm
Light pen	1. Touch tip of pen to desired icon 2. Press button or press pen on icon again to confirm
Trackball	1. Roll ball to select desired icon with cursor 2. Press button to confirm 3. Moving cursor "up" and "down" on screen means rolling ball away from and toward you.
Mouse	1. Slide mouse in desired direction of cursor movement, stopping on desired icon 2. Press button on mouse to confirm 3. Do not move mouse while pressing button 4. Keep mouse flat on surface 5. Keep mouse in correct orientation 6. Moving cursor "up" and "down" on screen means sliding mouse away from and toward you 7. At edge of table, lift mouse and replace in center to continue cursor movement
Joystick	1. Press control shaft to move cursor to icon, release shaft to stop 2. Press button to confirm 3. Moving cursor "up" and "down" means pressing shaft away from and toward you
Arrow keys	1. Press appropriate keys to move cursor to icon 2. Press ENTER to confirm

References

Booth, P. (1989). An introduction to human-computer interaction. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Buxton, W. (1986). There's more to interaction than meets the eye: Some issues in manual input. In D. A. Norman & S. W. Draper (Eds.), User centered system design (pp. 319-337). Lawrence Erlbaum Associates, Hillsdale, NJ.

Case, R. (1985). Intellectual development: Birth to adulthood. Orlando, FL: Academic Press.

Mackinlay, J., Card, S. K., & Robertson, G. G. (1990) A semantic analysis of the design space of input devices. Human-Computer Interaction, 5, 145 - 190.

Olson, J. R., & Olson, G. M. (1990). The growth of cognitive modeling in human-computer interaction since GOMS. Human-Computer Interaction, 5, 221 - 265.

Pasual-Leone, J. & Ijaz, H. (1989). Mental capacity testing as a form of intellectual-developmental assessment. In Samuda, R. J., Kong, S. L., Cummins, J., Pascual-Leone, J., & Lewis, J., Assessment and placement of minority students, (pp. 143-171). Toronto: C.J. Hogrefe/Intercultural Social Sciences Publications.

Revelle, G. L. & Strommen, E. F. (1990). The effects of practice and input device used on young children's computer control. Journal of Computing in Childhood Education, 2(1), 33-41.

Revelle, G. L., Strommen, E., & Offerman, S. (1990). Cursor and device differences in children's computer control. Unpublished manuscript.

Strommen, E. F., Razavi, S., & Medoff, L. M. (1992). This button makes you go up: three-year-olds and the Nintendo controller. Applied Ergonomics, 23, 409-413.

Strommen, E. F. & Revelle, G. L. (1990). Research in Interactive Technologies at Children's Television Workshop. Educational Technology Research and Development, 38(4), 65-80.

Strommen, E. F. (1992). Formative studies in the development of a new computer pointing device for young children. Educational Technology, 32(4), 43-51.

Strommen, E. F. (April, 1993). Joystick, mouse, or trackball?: Preschoolers' competence with three common input devices. Presented at the Annual Meeting of the American Educational Research Association, Atlanta, GA.